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# Erosion and Sediment Control Basic Course

# Module 2:

## Defining Erosion and it's impacts

# Module 2

## Introduction

# To be discussed in this Module:

- Definitions
- Sources of sediment
- 5 Stages of erosion
- 4 Factors influencing erosion
- The Main Principles of ESC
- Environmental Impacts of Erosion and Sedimentation
- Sediment in Stormwater

# Module 2a.

## Erosion Defined

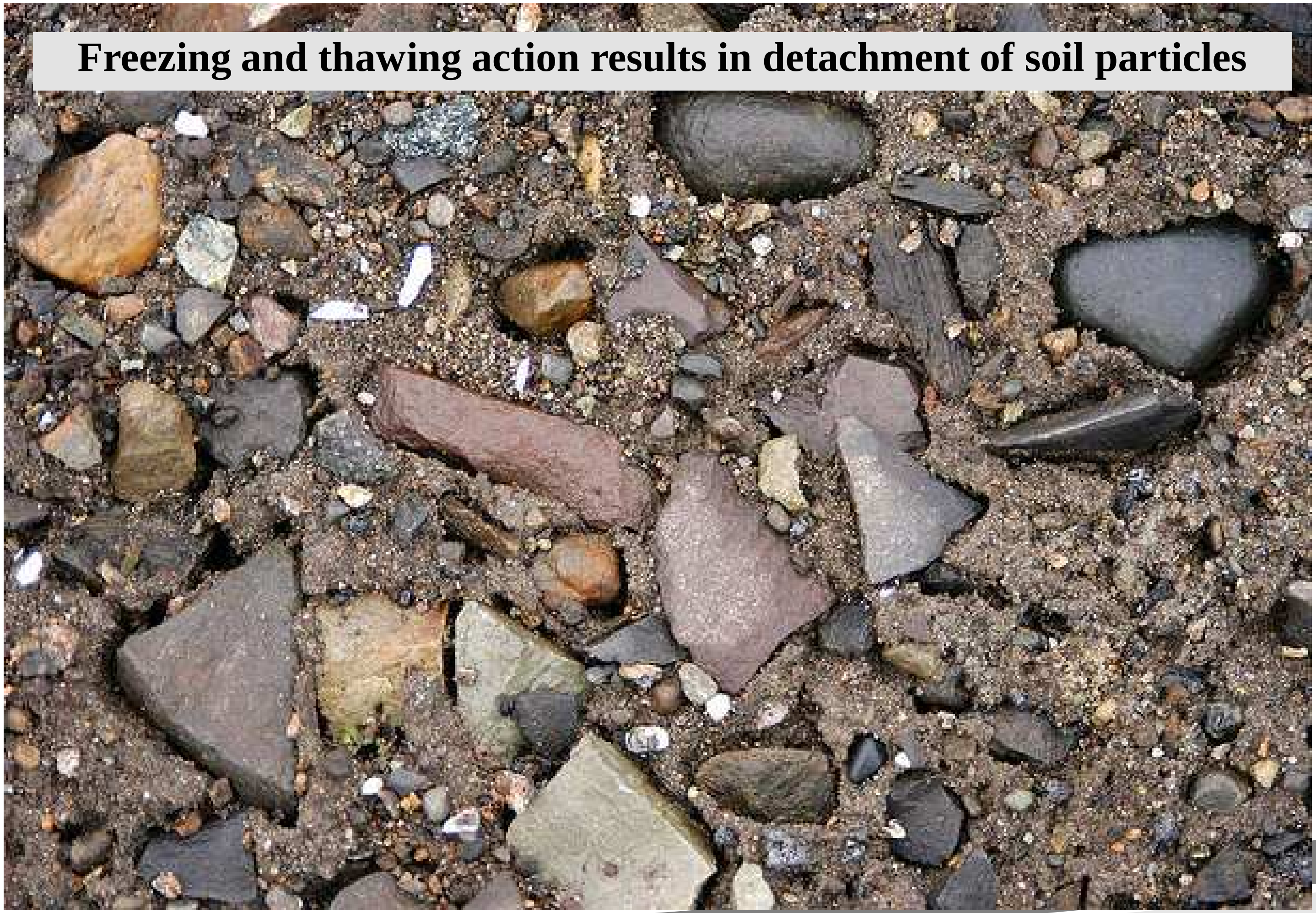
# What is Erosion?

**Soil erosion is defined as the removal of the land surface by erosive forces such as:**

# ...........water,

# .......wind,

# ……. ice,


Freezing and thawing action results in detachment of soil particles

# *and by gravity.*

# …or a combination of all the forces that cause erosion

# Module 2b

## Sources of Sediment

**Two Sources**

- Geologic (30%)
- Accelerated (70%)

**Five Stages**

- Raindrop (90%)
- Sheet
- Rill
- Gully
- Channel

**Four Contributing Factors**

- Climate
- Soils
- Slope
- Ground cover

# Geologic vs. Accelerated Erosion

| Geologic | Accelerated |
|---|---|
| Natural Process | Caused by Humans - Agriculture, mining, forestry and development (land disturbance) |
| 30% | 70% |


# Geologic Erosion(Natural Process 30%)

## *Grand Canyon*

# Examples of Geologic Erosion in Virginia

## Natural Tunnel

## Natural Bridge

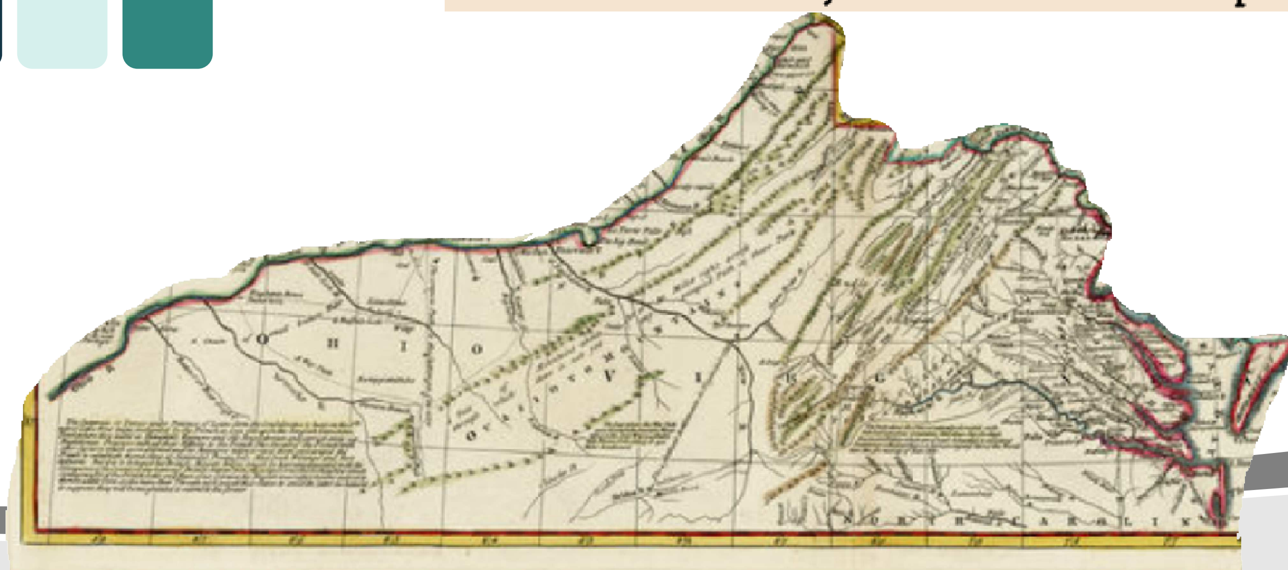
# Accelerated Erosion (Human Caused Process 70%)

## Geologic rate increased by man's intervention

# History Repeats Itself?

Peters, dated March 16, 1753.[63] His recognition of some present-day problems, conservation and flood-control, is seen. "Our Runs dry up apace, several which formerly would turn a fulling mill, are now scarce sufficient for the use of a farm. The Reason of which is This,

when the country was cover'd with Woods, and The Swamps with Brush, The rain that fell was detained by These Interruptions, and so had time to insinuate into the Earth, and contribute to the Springs and Runs. . . . But now the Country is clear'd, the Rain as fast as it falls, is hurried into the Rivers, and washes away the Earth and Soil of our Naked Fields, fills and choaks the Springs, and makes Shoals



# Major "Activities" that cause Accelerated Erosion

## Agriculture

# Major "Activities" that cause Accelerated Erosion

## Surface Mining

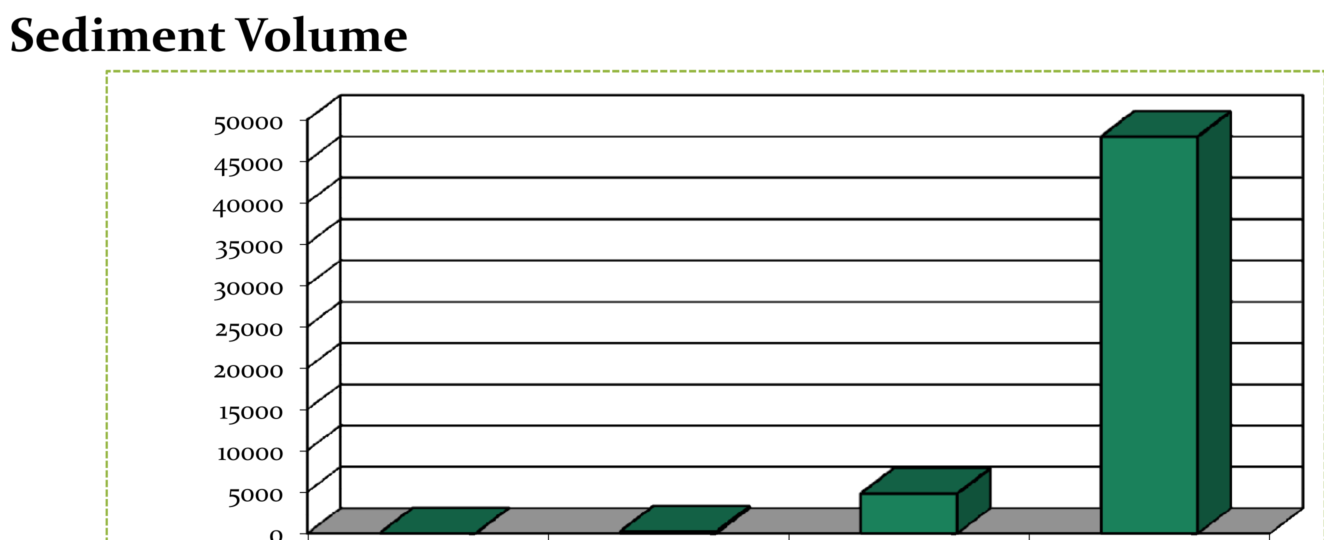
# Major “Activities” that cause Accelerated Erosion

## Forestry

# Major “Activities” that cause Accelerated Erosion

## Urban Construction

# Sediment Production (Table 2-1)




| | Forest | Grass land | Crop land | Construction |
|---|---|---|---|---|
| T/SqMi/Y | 24 | 240 | 4,800 | 48,000 |

Rate of erosion is greater per acre on urban construction projects.

# Module 2c.

## Five Stages of Soil Erosion

- Raindrop Erosion
- Sheet Erosion
- Rill Erosion
- Gully Erosion
- Channel Erosion

# How does it all begin?

# Rain

## Rainfall is the primary concern:

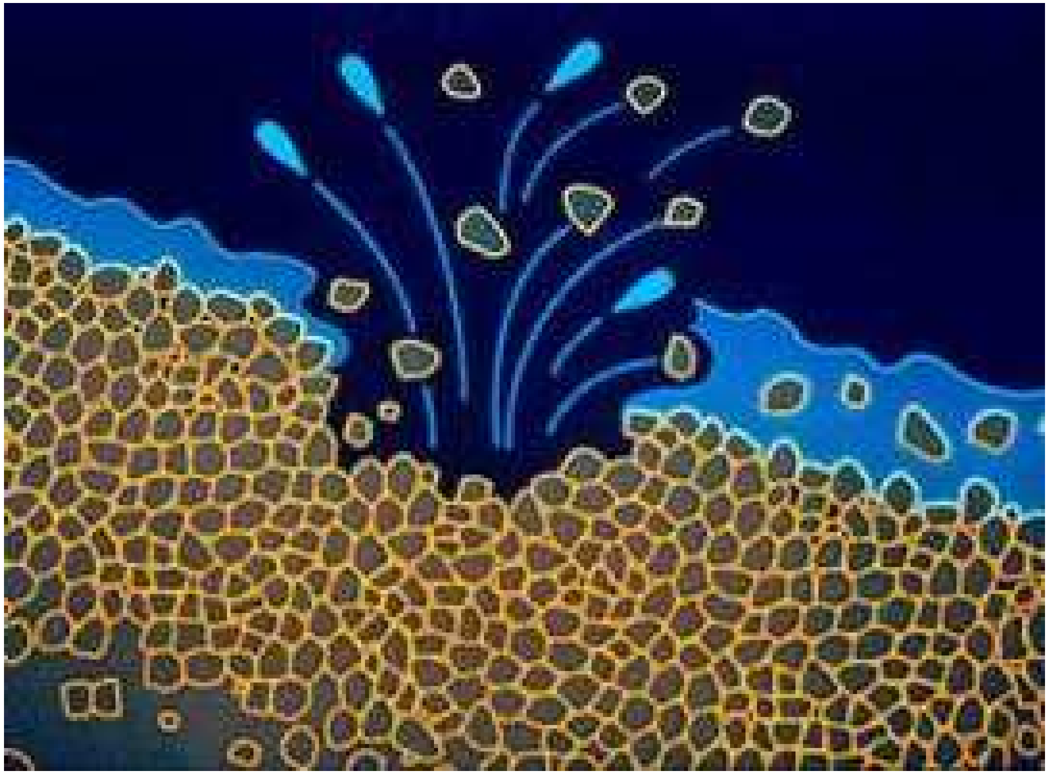
Effects of Raindrops

Effects of Runoff

# Raindrop Impact

- First effect on soil
- Dislodges soil particles
- Splashes
- Becomes sheet erosion

# Raindrop Impact



- **Action of falling rain equals 90% or more of total soil erosion**

# Raindrop Impact

- Raindrops hit the exposed soil like tiny bombs
- Larger raindrops strike the soil surface harder

# Raindrop Impact

- Soil surfaces that are covered from the raindrop impact are protected



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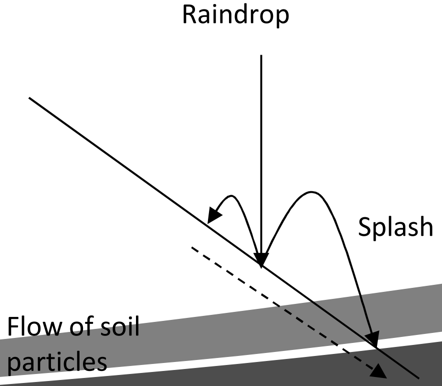
# Raindrop Impact

- Exposed soil particles are detached and splashed from the point of impact
- More than 100 tons of soil per acre may be detached in a single rainfall
- Splash effect can be seen on buildings and plants nearby

# Raindrop Impact

- Particles can be moved as far as 2 feet vertically to 5 feet horizontally
- On a 10% slope, 75% of the soil movement is down-slope



# Raindrop Impacts

- Rain also compacts the soil on impact
- Repeated strikes change the surface of the soil into a slurry
- The slurry seals the soil pore space and prohibits the water from infiltrating

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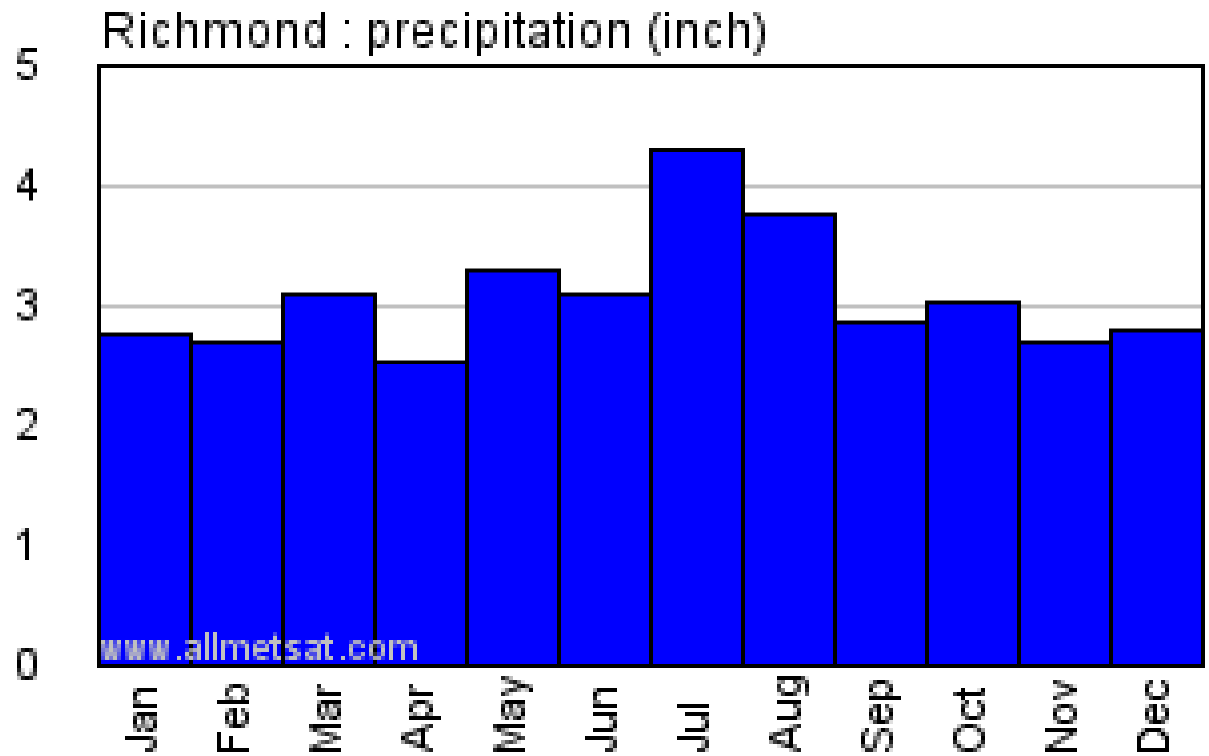
# Rainfall Distribution

- Rainfall is not evenly distributed throughout the year
- Most erosive rainfall is during the months of June – Sept. (Table 2-2, page 9)



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# Sheet Erosion

- Shallow sheets of water run across the surface
- Seldom detaches soil particles but…
- Transports detached soil
- Sheet flow moves only a short distance before it concentrates or diminishes

# Rill Erosion

- Shallow water collects in low spots
- Deeper flow means more concentrated quantity of water
- Velocity of water becomes greater
- Creates tiny channels down the slope
- Usually easily repaired

# Gully Erosion

- Volume and velocity increases
- Creates larger channels or cuts
- Too large to be easily repaired
- May Require Heavy Equipment to repair

# Channel Erosion

Greater volume & velocity of water.

Causes movement of materials within the stream bed & banks.



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# Runoff

- **Another damaging aspect of rainfall is Runoff**
- **Runoff begins when the amount of rainfall exceeds the soil's capacity to absorb water**



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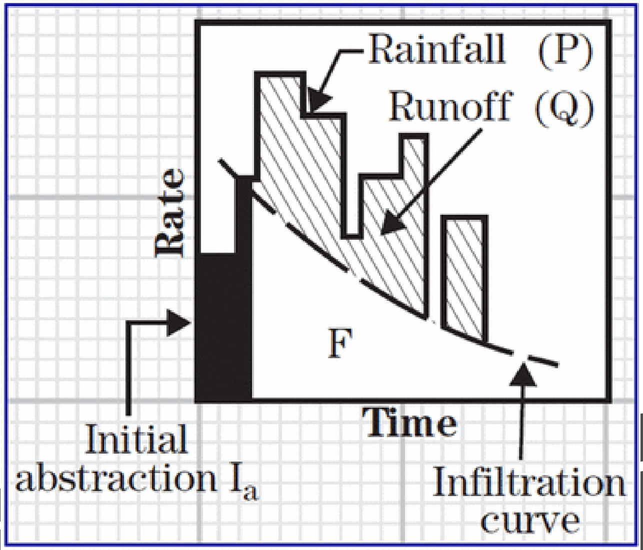
# Runoff

- Runoff can begin in a matter of a few minutes after the start of rain
- The amount of runoff depends on the amount & intensity of rain and the nature of the soil surface



# Runoff

- Runoff starts as sheet flow, which is a major agent in transporting soil particles
- Generally shallow and has very little velocity
- Usually does not detach soil particles but will transport particles detached by raindrop impact

# Runoff

- As the depth of sheet flow moves down-hill, it begins to concentrate in low spots
- Beginning of concentrated flow
- As the runoff concentrates, it gains force & momentum to detach other soil particles
- A "chain reaction" occurs where depth & velocity of runoff increase



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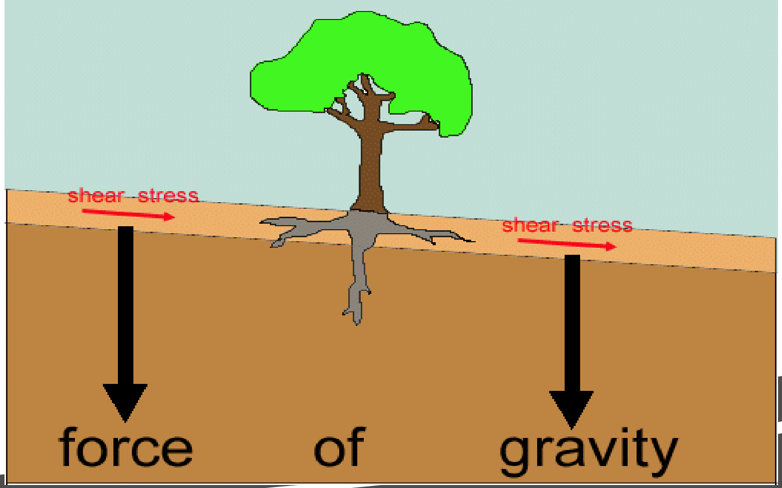
# Concentrated Flow

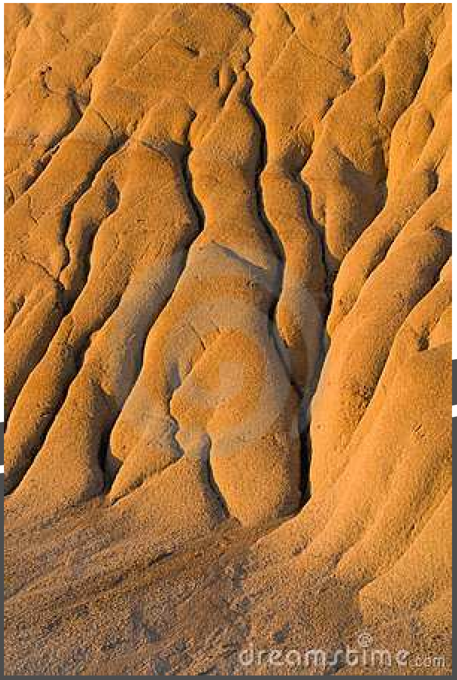
- The detachment of soil by flowing water is confined to the areas of concentrated flow (rills, gullies, channels)
- The soil is detached by rolling, lifting and abrasive actions (the force is horizontal)
- As velocity increases, vertical currents (eddies) occur to lift particles
- This is called "turbulence"



# Concentrated Flow

- **Detachment & transport is determined by the water volume and velocity**

- **The erosive capacity of flowing water depends on velocity, turbulence, amount & type of abrasive material flow, the roughness of the channel and slope gradient and length**



The energy of runoff is a function of: slope gradient; slope length; and runoff volume.

The greater the energy of the runoff and/or the greater the turbulence of water, the more erosive it is.

# Video

# Module 2d.

## Four Factors Influencing Erodibility of soil



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# Four Factors Influencing Erodibility

## Climate

- Precipitation
- Frost
- Wind

## Soil

- Structure
- K-factor
- Particle size distribution

## Topography

- Steepness
- Length
- Configuration

## Groundcover

**Erodibility** is the vulnerability of a material to erode

# Four Factors Influencing Erodibility

## Climate

- Precipitation
- Freeze-thaw-drought effects
- Wind

- Precipitation:
  - Type
  - Intensity
  - Raindrop size
- Temperature extremes
- Wind

# Four Factors Influencing Erodibility


## Soil

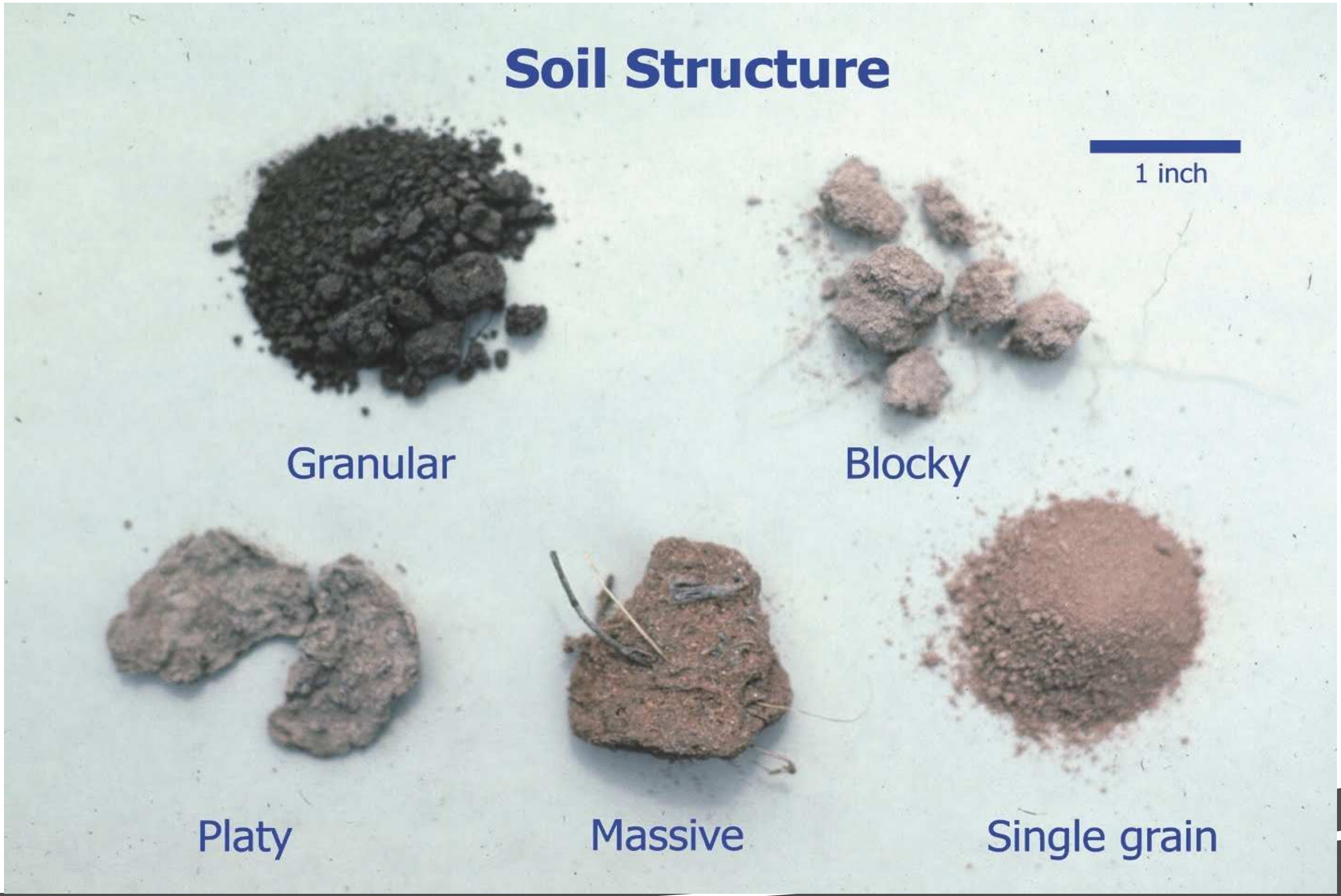
- Structure
- K-factor
- Particle size distribution

**Soil properties influencing erodibility:**

1. Structure
2. Texture
3. Bulk Density
4. Organic matter
5. Infiltration and permeability rates

→ Ability to develop a self sustaining ground cover (MS-3)

# Soil Structure



# Soil Structure

- Erodibility increases with silt (.002-.05mm) and very fine sand (.05-0.1 mm)
- Decreases with larger sand (0.1 to 2 mm) and clay (< or = to .002 mm) and organic matter content
  - High clay soils are more resistant to detachment, but once detached are easily transported
  - Organic material makes soils more permeable- improves structure & stability of soil

# Four Factors Influencing Erodibility

## Soil

- Structure
- K-factor
- Particle size distribution

**Soil properties influencing erodibility:**

1. Structure
2. Texture
3. Bulk Density
4. Organic matter
5. Infiltration and permeability rates

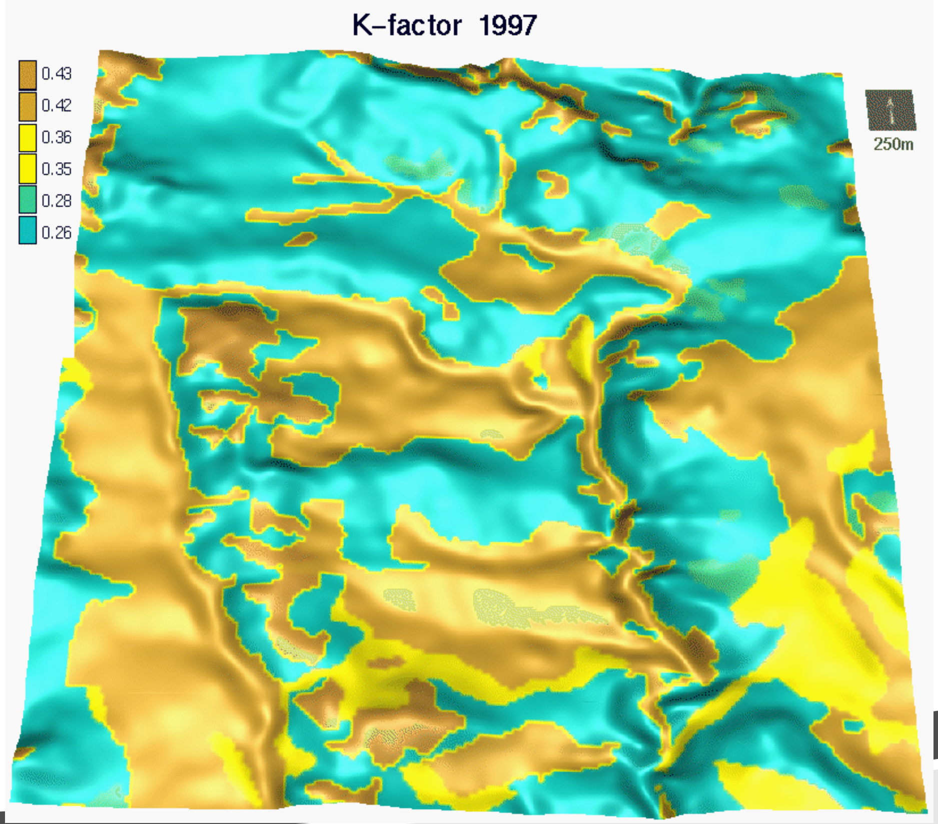
Soil Erodibility Factor (K-Factor)

# Erodibility of Soil (K-factor)

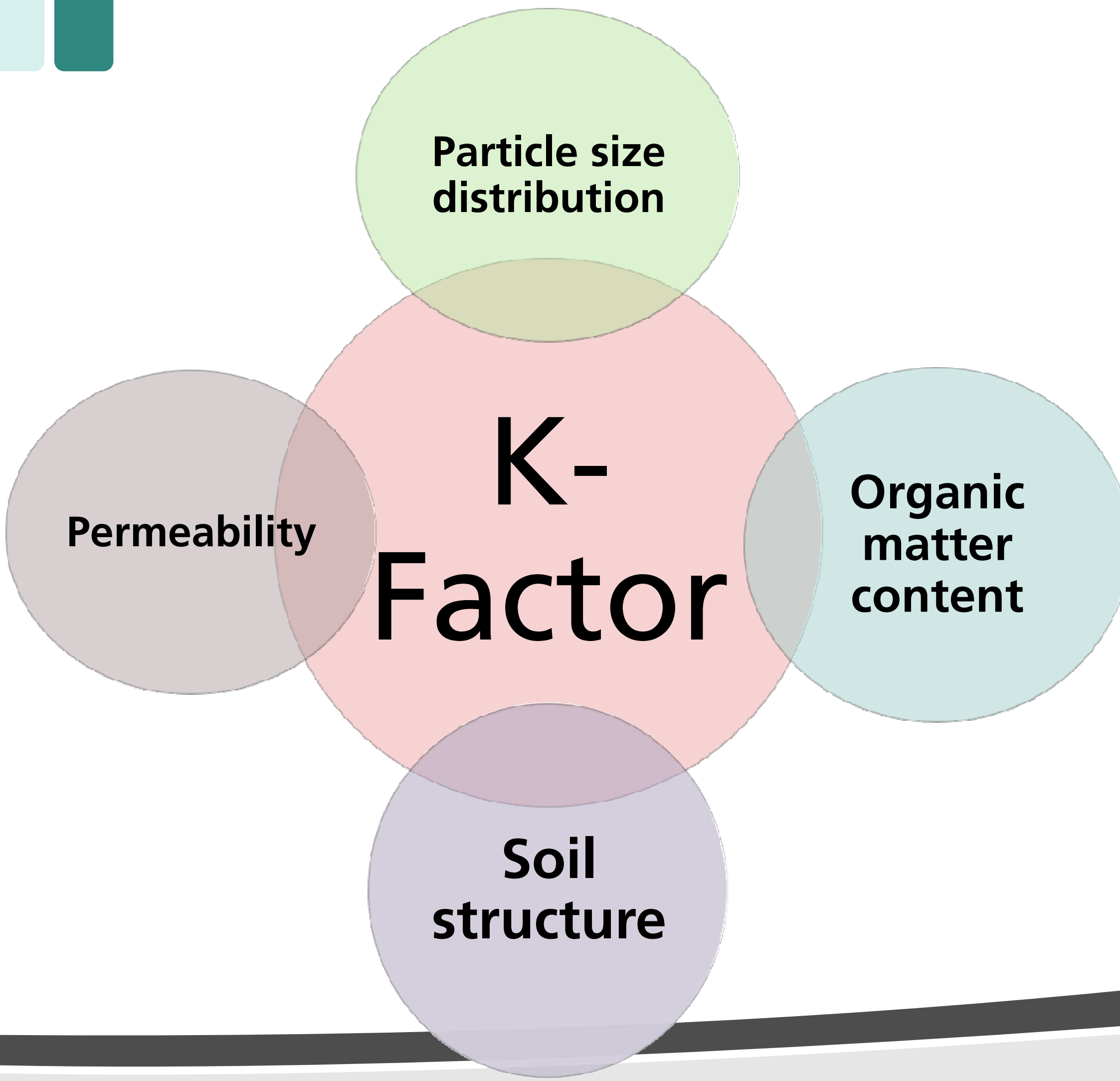
## Different soils will erode at different rates

➔ The K-factor

***The K-factor assists us to determine how erodible a soil is.***

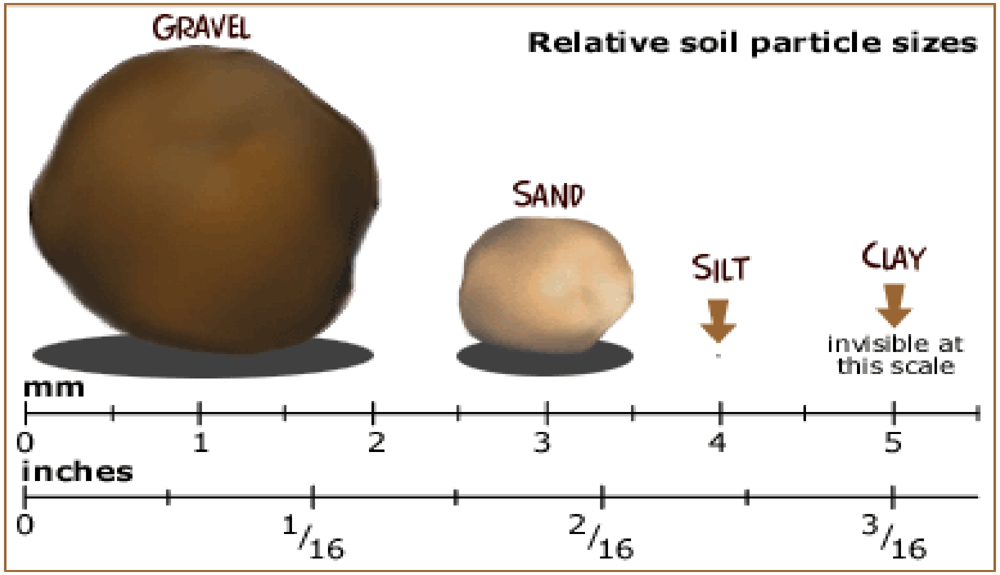


# Erodibility of Soil (K-factor)




# Erodibility of Soil (K-factor)

- **Soils consist of a combination of small particles:**




| *Name of soil separate* | *Diameter limits (mm) (USDA classification)* |
|---|---|
| Clay | less than 0.002 |
| Silt | 0.002–0.05 |
| Very fine sand | 0.05–0.10 |
| Fine sand | 0.10–0.25 |
| Medium sand | 0.25–0.50 |
| Coarse sand | 0.50–1.00 |
| Very coarse sand | 1.00–2.00 |



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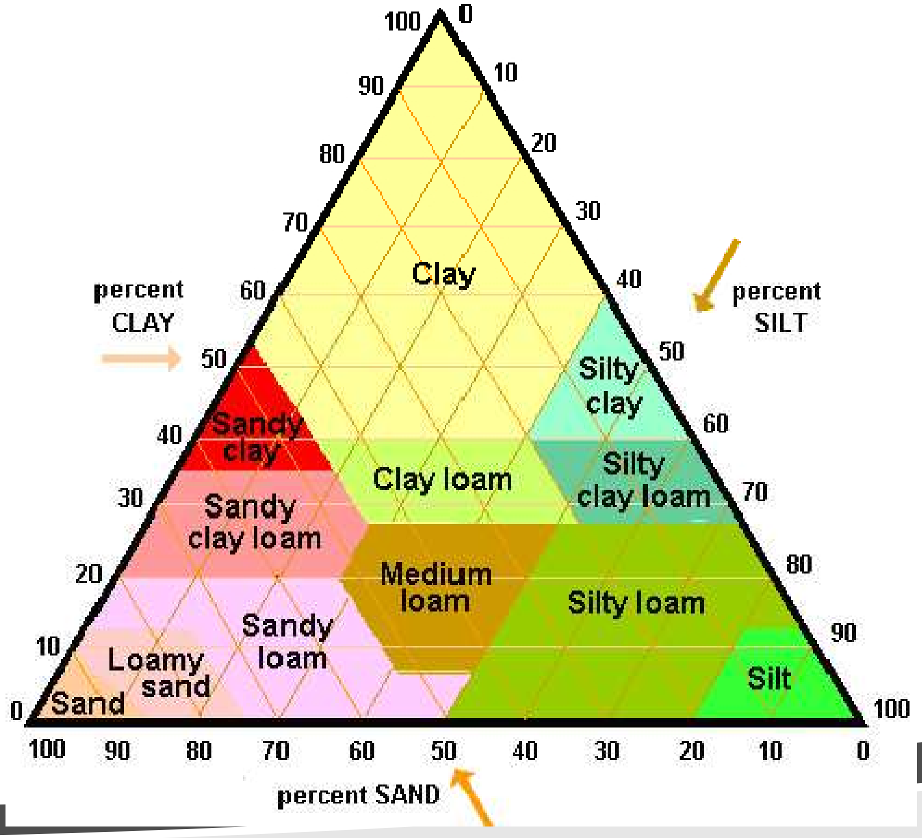
# Soil particle size and classification

- Soils consist of a combination of small particles:



# Erodibility of Soil (K-factor)

## Soil properties that influence erodibility:

- Infiltration rate-rate at which water enters soil
- Permeability-rate at which water moves through soil
- Total water holding capacity
- Detachment rate by raindrop impact & flowing water impacts
- Ability to resist transporting forces

# Erodibility of Soil (K-factor)

- Soil erodibility has been studied intensively
- The Universal Soil Loss Equation was developed to predict long term soil loss on agricultural land
- Modified for use in urban setting
- Provides a model to predict how soil loss can be reduced by implementing ESC controls

# Erodibility of Soil (K-factor)

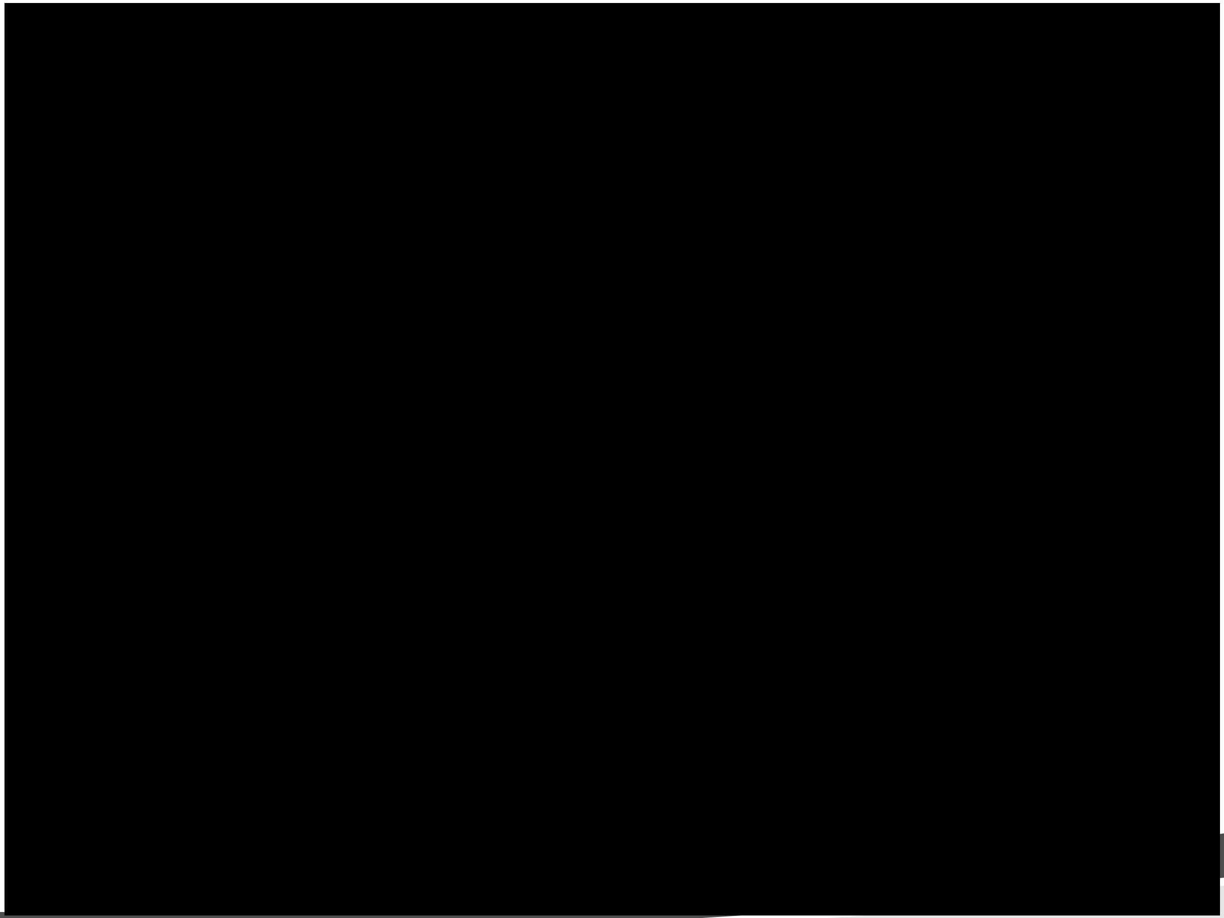
**K - factors**

*X < 0.23 → low erodibility*

*0.24-0.36 → moderate erodibility*

*X > 0.37 → high erodibility*

# Video



# Four Factors Influencing Erodibility

## Topography

- Steepness
- Length
- Shape

**Energy = Volume X Speed**

The energy of runoff is a function of slope angle, slope length, and volume of the runoff.

The greater the energy of the runoff and/or the greater the turbulence of water is, the more erosive it is.

More Energy Means Higher Erodibilty

# Slope Steepness

The steepness of a slope causes velocity (speed) of the runoff to increase.

Less chance for water to infiltrate on a steep slope
➔ More runoff

**Energy=Volume x Speed**

Three categories of erodibility (Table 2.3):

| Slope gradient | Erosion hazard |
|---|---|
| 0-7% | Low |
| 7-15% | Moderate |
| 15% & over | High |

# Slope Length

**The longer the slope**

- **the greater the depth of runoff**
- **the greater the velocity (speed of the runoff)**

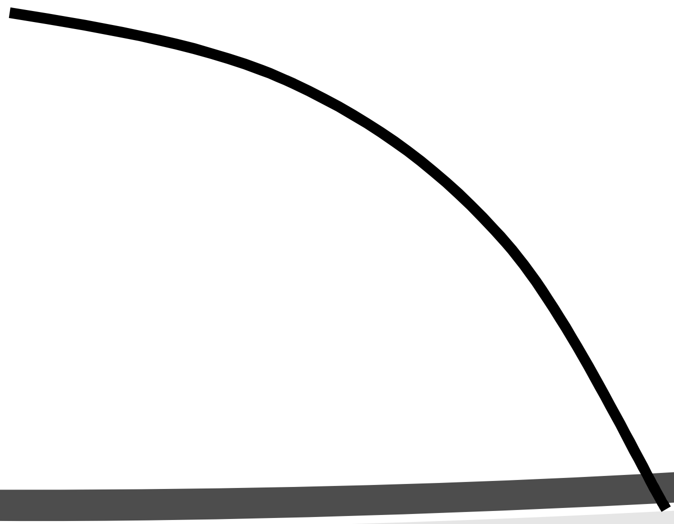
**Energy=Volume x Speed**

**TABLE 2.4.**
**SLOPE GRADIENT AND LENGTH COMBINATIONS AT WHICH THE EROSION HAZARD WILL BECOME CRITICAL**

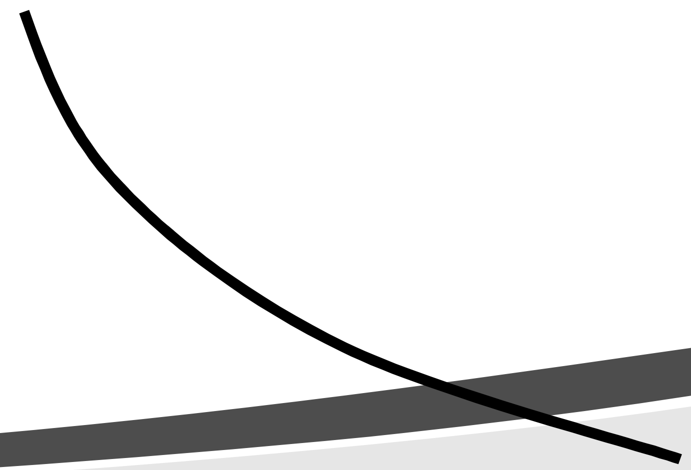
| Slope gradient | Slope length |
|---|---|
| 0-7% | 300 feet (100 meters) |
| 7-15% | 150 feet (50 meters) |
| 15% & over | 75 feet (25 meters) |

# Slope Shape

- Convex slopes (steeper at the lower end) have more erosion potential



- Concave slopes (steeper at the top or upper end & flatter at the lower end) have less potential for erosion



# Four Factors Influencing Erodibility

**Groundcover**

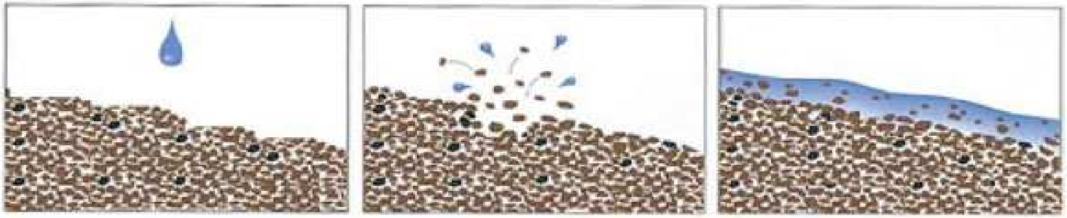
- **<u>Most important</u> factor from the standpoint of controlling erosion.**
- **Amount of erosion is directly proportionate to the amount of bare soil exposed to raindrop impact**
- **Dramatic reductions in soil loss can be obtained simply by covering the soil surface to protect it from raindrop impact**

**TABLE 2.5.**
**EFFECTIVENESS OF VARIOUS GROUND COVERS IN PREVENTING SOIL EROSION**
***(this table compares fully established stands of groundcover with bare soil)***

| Type of Ground Cover | Percent Reduction |
|---|---|
| Permanent grass | 99 |
| Perennial ryegrass | 95 |
| Annual ryegrass | 90 |
| Small grains | 95 |
| Millet or Sudan grass | 65 |
| Field bromegrass | 97 |
| Grass sod | 99 |
| Hay or straw (@2 tons/acre) | 98 |

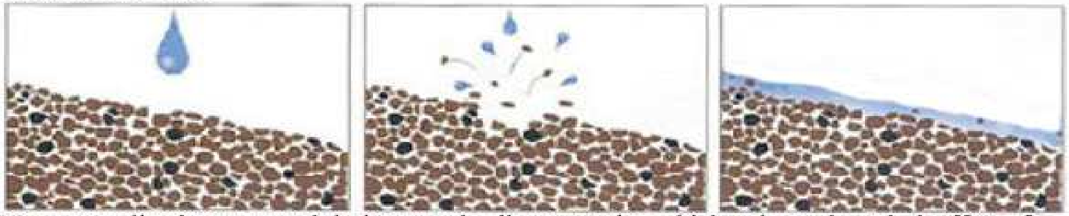
# Benefits of Vegetative Ground Cover

- Prevents raindrop impact
- Prevents puddling and sealing of the soil
- Promotes higher infiltration rates
- Increases water uptake
- Reduces runoff velocity



With no protective cover, raindrops can splash soil particles up to 3' away. Soil particles and aggregates that have been detached are then transported down the slope by runoff water.

Residue cover cushions the fall of raindrops and reduces or eliminates splash erosion. Small natural dams are formed that cause ponding of runoff. Sediment is deposited in these ponds and remains in the field.



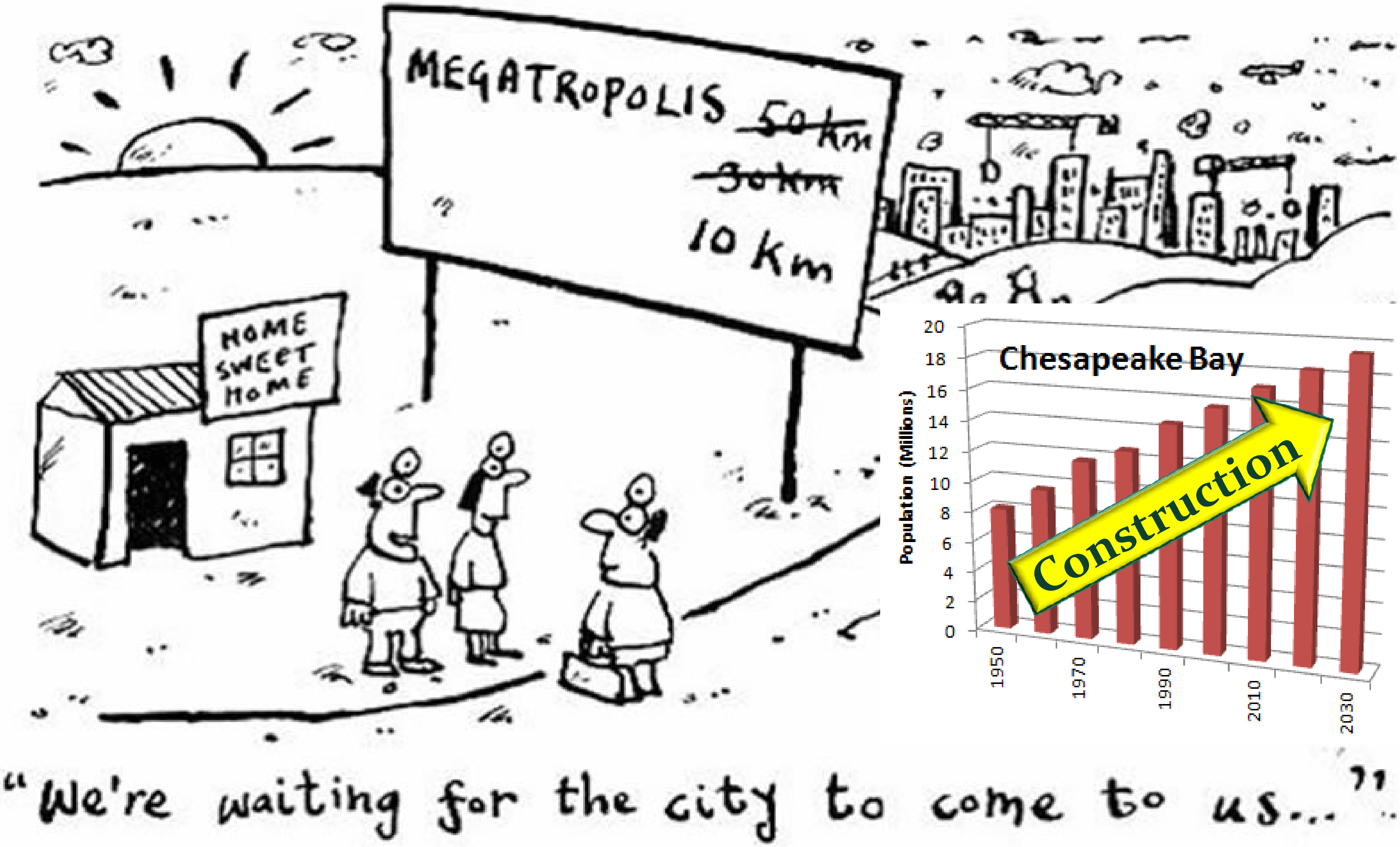
Manure application can result in improved soil aggregation which reduces the splash effect of raindrops and increases infiltration with reduced runoff.

# Module 2e.

## The Impacts Of Erosion And Sedimentation

# The Impacts Of Erosion And Sedimentation

- Over geologic time the Appalachian Mountains eroded away and the sediment was deposited off the coast, forming the coastal plain
- While geologic erosion has stayed relatively steady over the past thousand years, accelerated erosion has gradually increased with the growing human population


MEGATROPOLIS ~~50 km~~ ~~30 km~~ 10 km
HOME SWEET HOME
"We're waiting for the city to come to us..."
Chesapeake Bay
Population (Millions)
20
18
16
14
12
10
8
6
4
2
0
1950
1970
1990
2010
2030
Construction

# Impacts of Erosion and Sedimentation

Sediment transport

Pollutant runoff

Slope failure

Flooding

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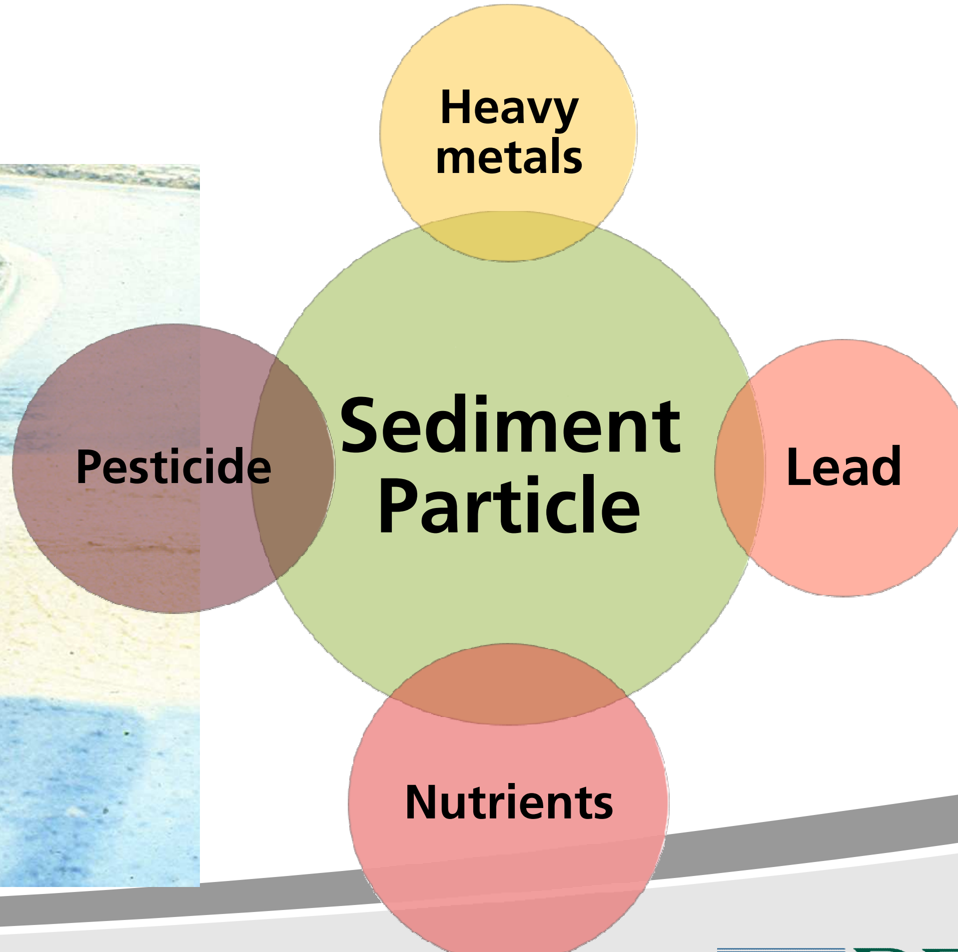
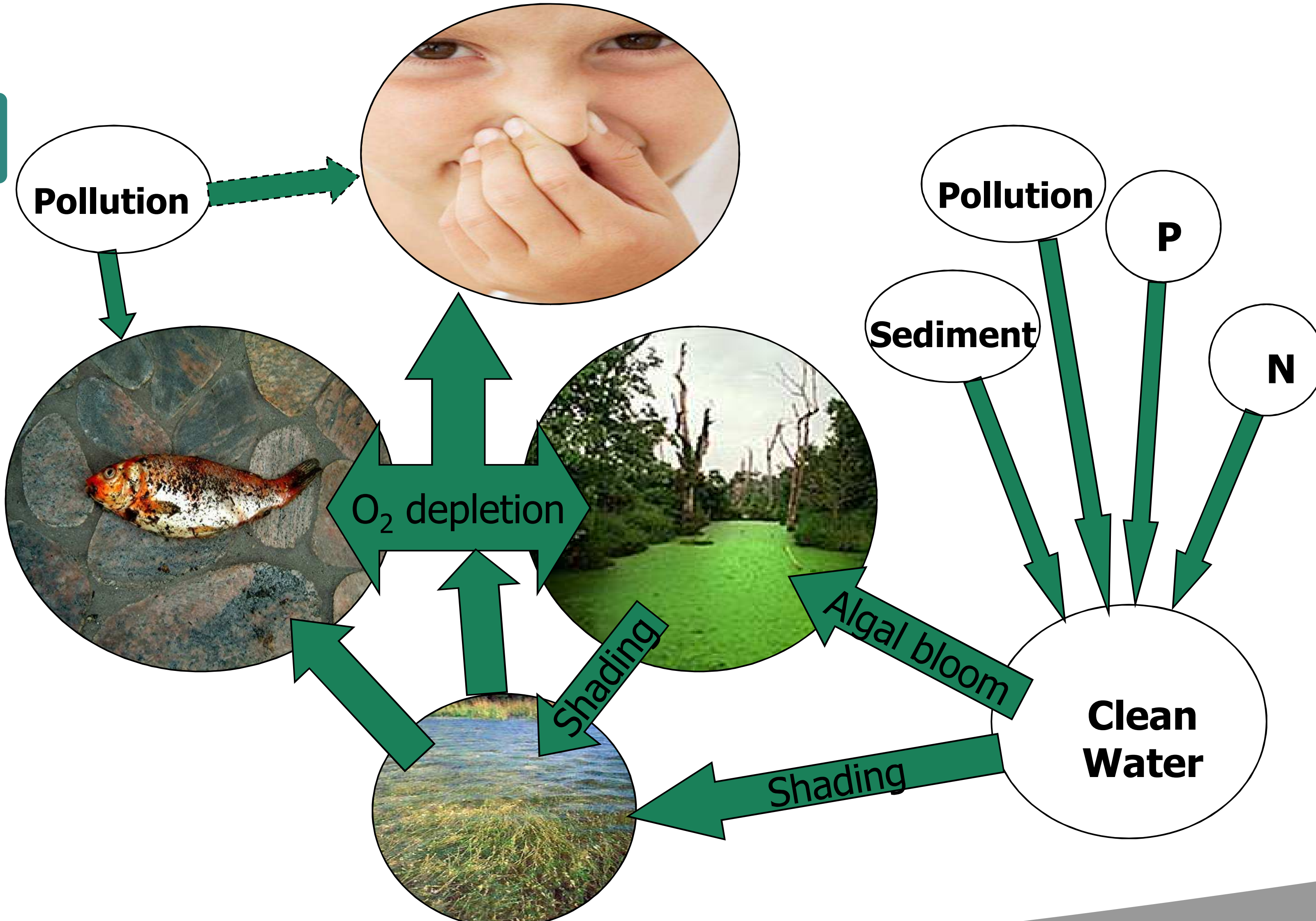
# Sediment particles have various other chemical compounds stuck to them




Pollution
$O_2$ depletion
Shading
Algal bloom
Shading
Pollution
P
Sediment
N
Clean Water

# Impacts of Erosion and Sedimentation

**Socio/Economic**

**Environmental**

# Impacts of Erosion and Sedimentation

**Precipitation**
- Rain
- Snow

**Erosion**
- Raindrop
- Sheet
- Rill
- Gully
- Channel

**Sediment Transport**
- Soil's infiltration capacity exceeded
- Overland flow & into conveyance system

# Sediment Production in the U.S.

4 billion tons of sediment
≈ 80,000,000,000 Cu. Yds

1,300,000,000 CY is deposited in drinking water reservoirs

=270 billion gallons of water

= drinking water for 5.5 million people



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# Sediment Production in the U.S.

In addition to filling up reservoirs, sediment may also block shipping channels.

**46%** of our imported goods come via navigable water ways

# Dredging

**TABLE 2.6. AMOUNT OF SEDIMENT REMOVED BY DREDGING IN THE US AND ASSOCIATED COST FROM 2001 TO 2009 (SOURCE U.S. ARMY CORPS OF ENGINEERS).**

| Year | Sediment Removed (CY) | Total Cost | Cost per CY |
|---|---|---|---|
| 2001 | 268,468,100 | $ 867,758,200 | $ 3.23 |
| 2002 | 248,579,800 | $ 1,850,096,400 | $ 7.44 |
| 2003 | 233,804,500 | $ 887,345,900 | $ 3.80 |
| 2004 | 265,240,900 | $ 903,132,300 | $ 3.41 |
| 2005 | 255,079,800 | $ 956,490,700 | $ 3.75 |
| 2006 | 204,281,000 | $ 966,187,600 | $ 4.73 |
| 2007 | 206,872,900 | $ 996,193,800 | $ 4.81 |
| 2008 | 216,450,200 | $ 1,011,725,200 | $ 4.67 |
| 2009 | 263,625,000 | $ 1,344,107,100 | $ 5.10 |

# Amount of sediment removed by dredging in VA & associated costs

| Year | Number of Contracts | Sediment Removed (CY) | Total Cost | Cost per CY |
|---|---|---|---|---|
| 2004 | 12 | 5,919,790 | $ 27,757,785 | $ 4.69 |
| 2005 | 6 | 2,394,600 | $ 9,217,654 | $ 3.85 |
| 2006 | 7 | 2,133,950 | $ 10,453,199 | $ 4.90 |
| 2007 | 6 | 3,510,000 | $ 26,046,734 | $ 7.42 |
| 2008 | 7 | 1,226,100 | $ 8,245,203 | $ 6.73 |
| 2009 | 17 | 2,659,600 | $ 18,031,070 | $ 6.78 |

# Other Impacts of Erosion and Sedimentation

- Aquatic habitat loss
- Commercial fisheries
- Commercial sports fisheries
- Recreational fisheries

# Other Impacts of Erosion and Sedimentation

- Clean-up of drinking water
- Loss of fertile topsoil
- Sediment deposition and cleanup in storm sewer systems
- In stream erosion

# Module 2f.

## Principles of Erosion and Sediment Control



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# Principles of Erosion & Sediment Control

Erosion Control - **first** line of defense. "If there is no erosion, there can be no sediment."

- Prevents damages associated with both erosion and sediment control
- The only practical approach in some instances (e.g., very fine sediments)

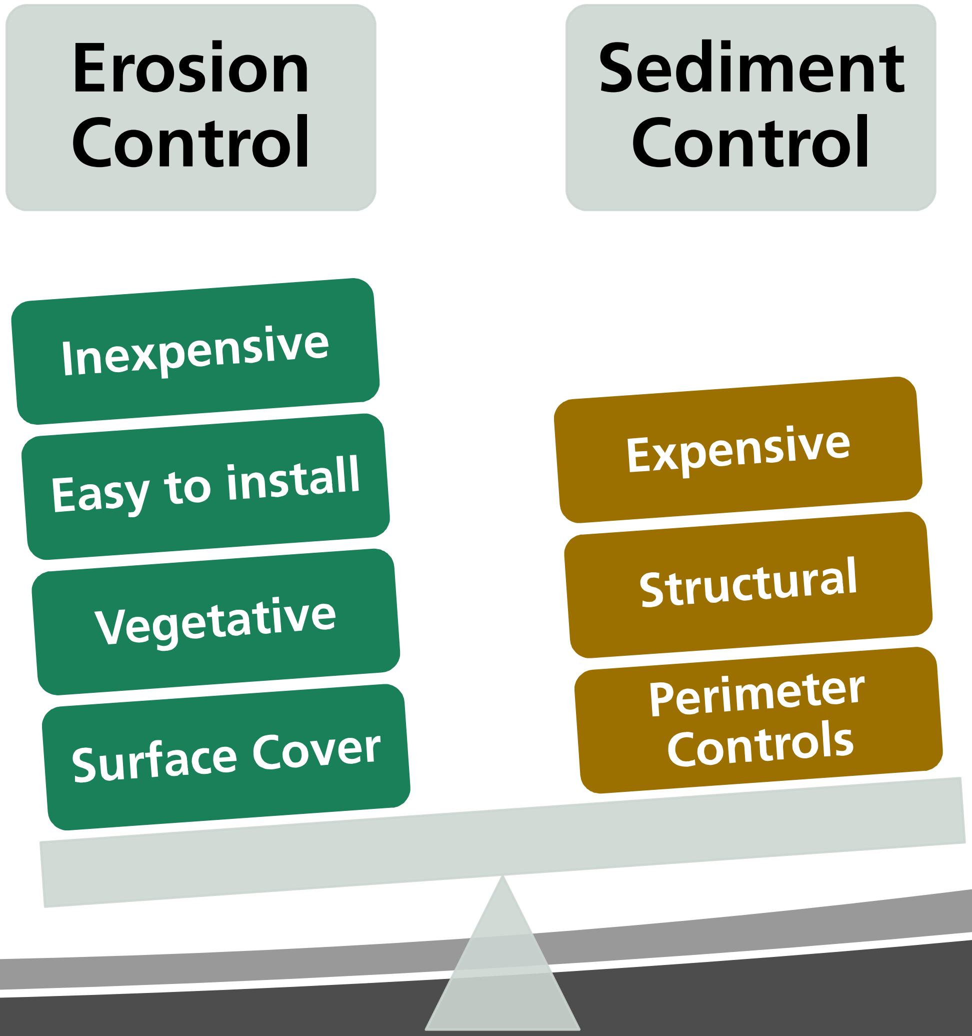
**Ground Cover!**

# Principles of Erosion & Sediment Control

**Sediment Control - subordinate to erosion control practices; <u>second</u> line of defense.**

**Coordination of erosion control, sediment control, & management of stormwater leaving the site is necessary for a well-integrated program!**

# Principles of Erosion & Sediment Control



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# Universal Soil Loss Equation

## Universal Soil Loss Equation (USLE) = mathematical model for a particular site

- Good indicator of potential erosion problems based on soil properties.
- Does not provide an accurate means to estimate sediment lost from a particular site

# Universal Soil Loss Equation

$$A = RKLSCP$$

A = average annual soil loss (tons/acre)
R = rainfall index
LS = topographic factor (L = slope length, S = slope grade)
K = soil erodibility factor
C = cropping factor
P = conservation practice (i.e., BMP) factor

# END OF MODULE 2

# QUESTIONS?